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(54) Coal hydrogenation process and apparatus having increased solids retention in ebullated bed reactor

(57) In e.g. the catalytic hydrogenation of coal, the concentration of unconverted coal solids in the reactor is increased by use of a coal solids deflecting means such as a baffle 30 located in the upper portion of the reactor upstream of the effluent stream withdrawal conduit opening. The solids deflection means preferably comprises a solid baffle attached to the reactor effluent withdrawal conduit upstream of its opening, and is preferably made removable from the reactor upper end.

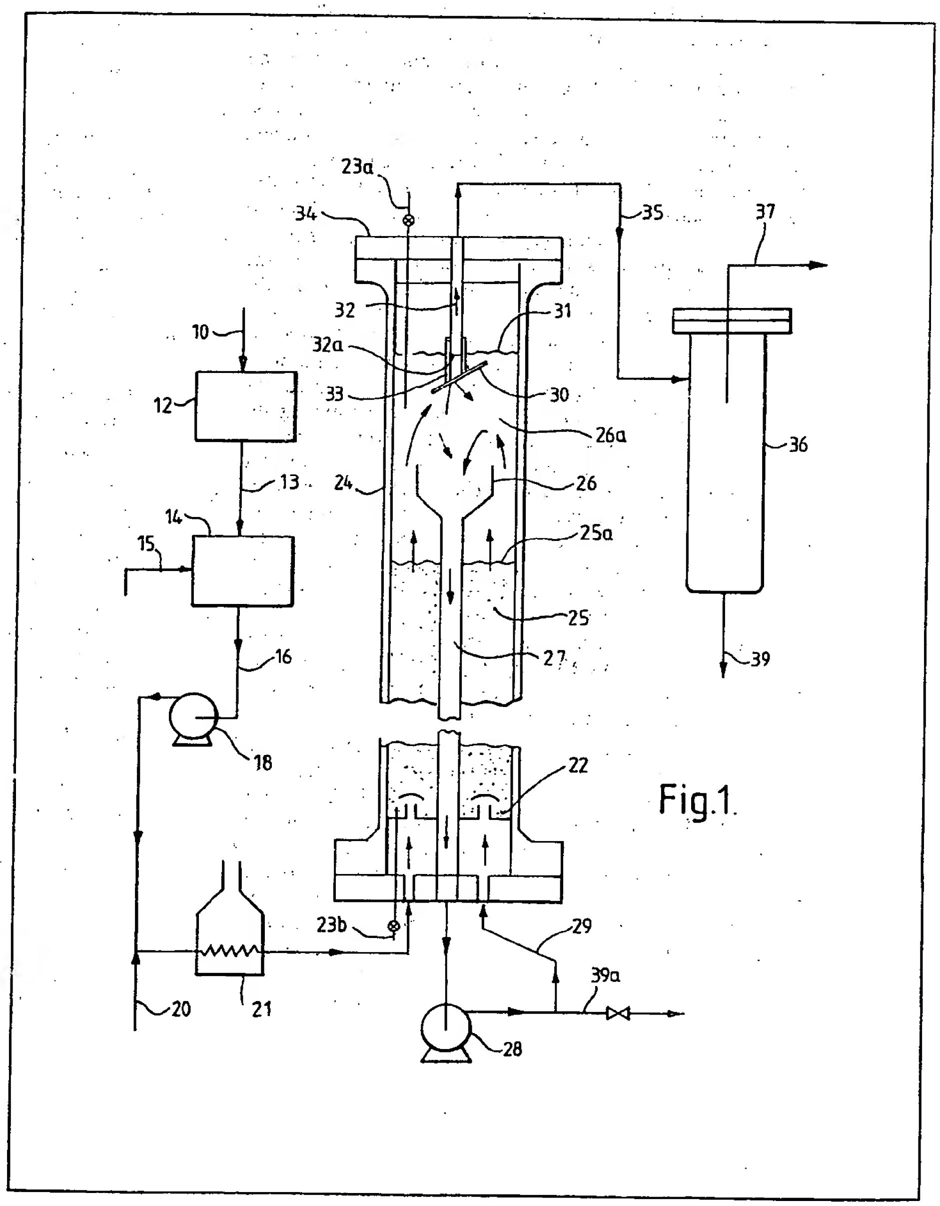

Fig.1.

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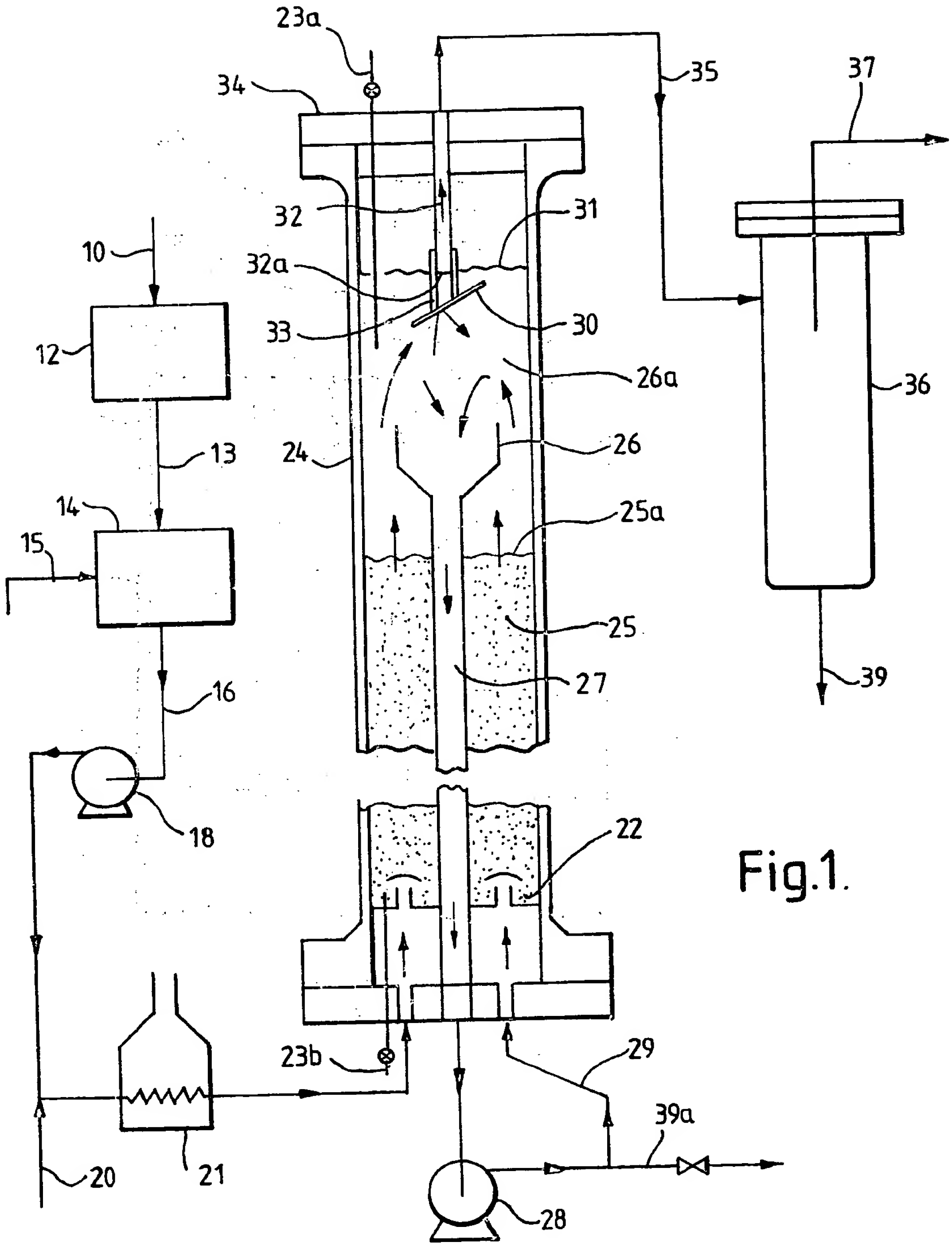
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Fig.1.

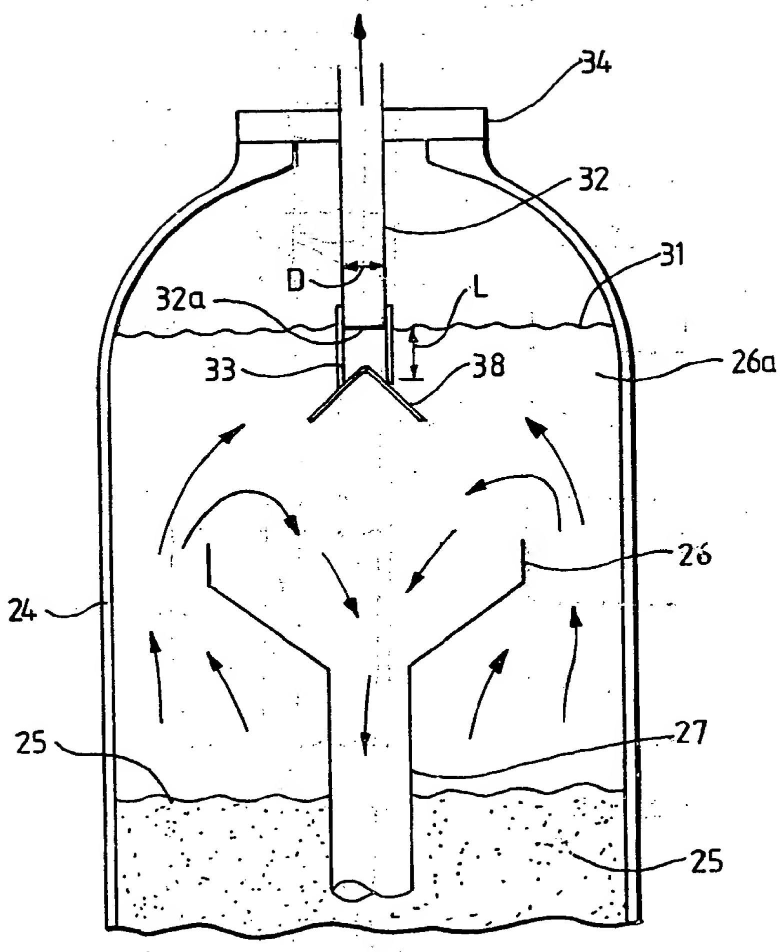

Fig.2.

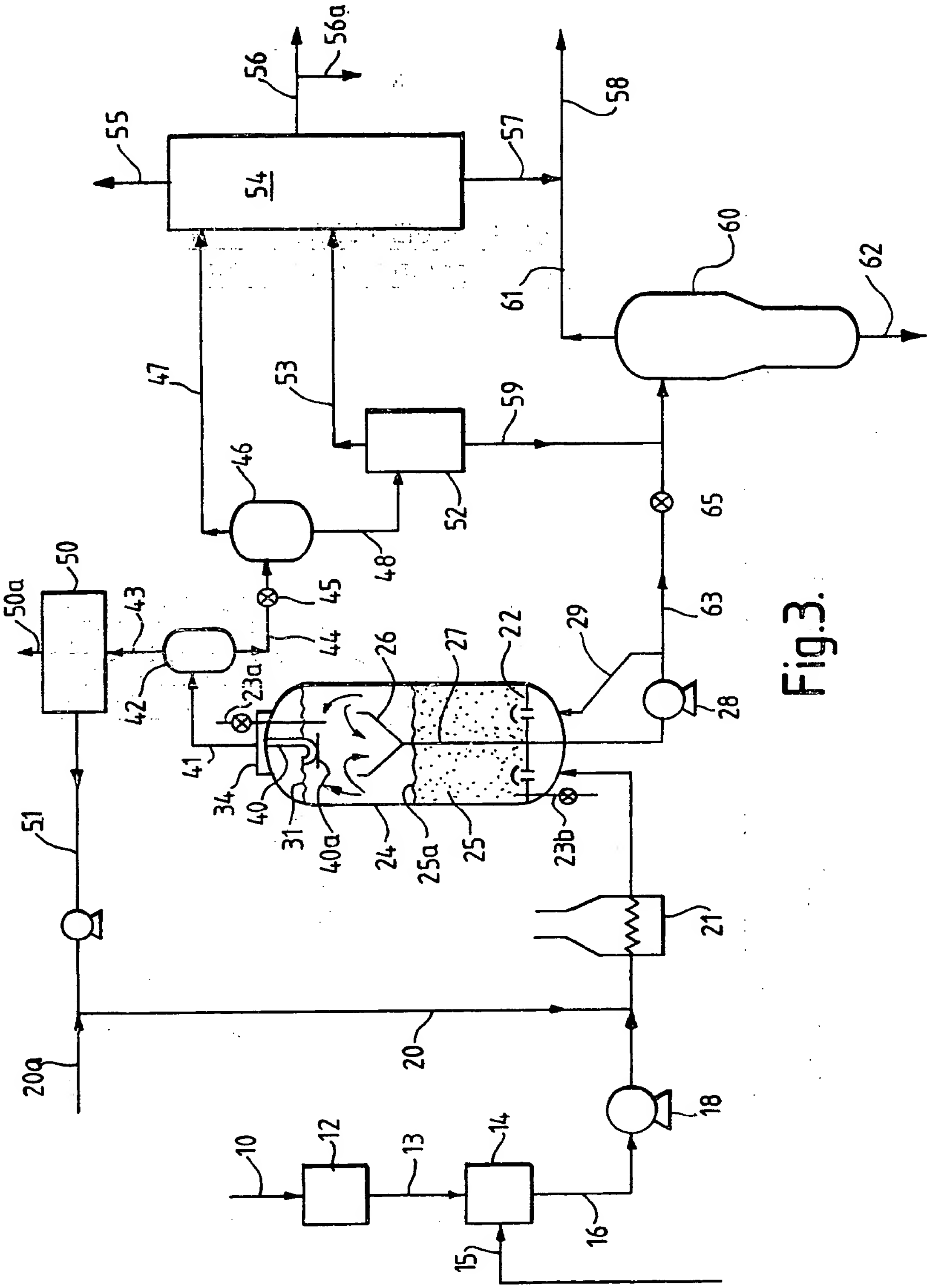
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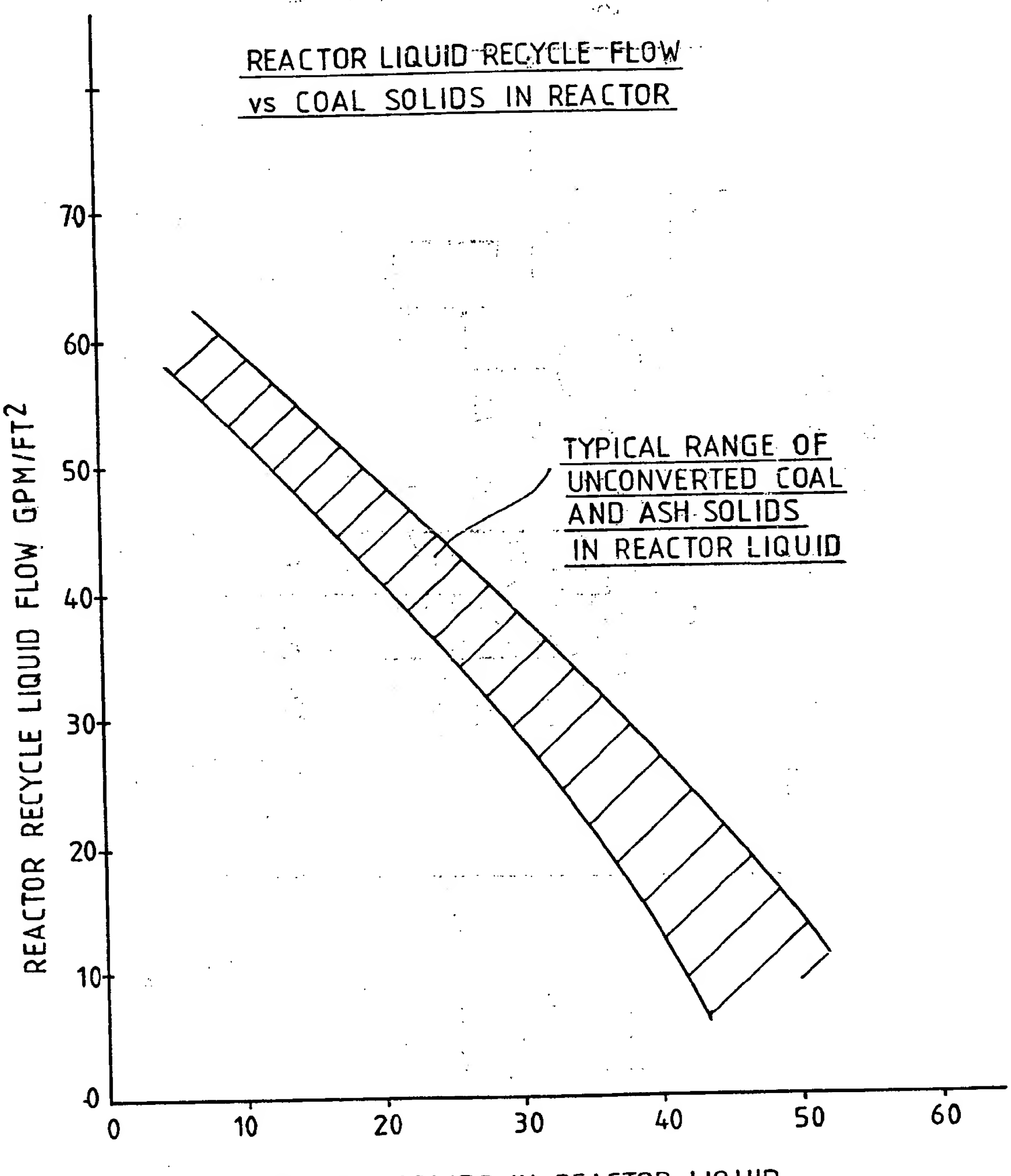
Fig.3.



REACTOR LIQUID RECYCLE FLOW
vs COAL SOLIDS IN REACTOR
TYPICAL RANGE OF
UNCONVERTED COAL
AND ASH SOLIDS
IN REACTOR LIQUID
REACTOR RECYCLE LIQUID FLOW GPM/FT2
0
10
20
30
40
50
60
70
0
10
20
30
40
50
60
WT. % COAL SOLIDS IN REACTOR LIQUID

Fig. 4.

SPECIFICATION

Coal hydrogenation process having increased solids retention in ebullated bed reactor

This invention relates to an improved process and apparatus for catalytic hydrogenation of coal to produce increased percentages of low-boiling hydrocarbon liquid products. It relates particularly to coal hydrogenation processes using an upflow ebullated catalyst bed type reactor in which an increased percentage of unconverted coal solids is retained in the reactor for further conversion reaction therein, thereby producing increased percentages of light hydrocarbon liquid and gas products.

In conventional ebullated catalyst bed reaction processes for the hydroconversion of hydrocarbon feedstocks, as described in U.S. Patent No. 3,519,555 to Keith et al, a reactor liquid concentration of a desired equilibrium product distribution is maintained as determined by the reactants and process conditions. A continuous reaction process exists with both internal and external recycled streams. In a conventional ebullated bed hydrogenation reaction process for coal, the reactor liquid solids concentration, which usually comprises about equal amounts of unconverted coal and ash, may range from 10 to 25 W % fine particulate solids. This solids concentration in the reactor is usually maintained by providing a liquid-solid separation step downstream of the reactor and recycling a liquid stream containing a reduced concentration of solids to the reactor, as generally taught by U.S. Patent No. 3,540,995 to Wolk et al. However, it is desirable to increase the percent hydroconversion of coal solids and semi-solid materials in the reactor so as to provide for increased yields of light hydrocarbon liquid products by using basically simpler solids separation procedures within the reaction zone, and thereby minimize or possibly avoid the need for providing an external liquid-solids separation step in the process.

U.S. Patent No. 3,188,286 to Van Driesen discloses a hydrocracking process for heavy hydrocarbon oils, which uses inclined wall-mounted baffles or a cylindrical screen within an ebullated bed catalytic reactor to help retain particulate catalyst material within the reactor. Also, U.S. Patent No. 3,677,716 to Weber et al discloses the use of a phase separation device located in the upper portion of an ebullated bed catalyst reactor to help retain catalyst in the reactor. However, a procedure or means for desirably retaining fine unconverted coal solids within an ebullated bed catalytic reactor for achieving increased conversion of such coal solids to hydrocarbon liquid products has apparently not been previously disclosed or used.

The present invention provides a process for hydrogenation of coal to produce hydrocarbon liquid and gas products, comprising;

(a) slurrying the coal with a hydrocarbon liquid and feeding the coal-oil slurry and hydrogen gas into a reactor containing particulate contact solids;

(b) passing said coal slurry and gas upwardly through the reactor under liquid phase conditions in which the solids are placed in random motion in the upflowing liquid, and at a temperature from 750 to 950°F (399 to 510°C) and hydrogen partial pressure from 1000 to 4000 psig (69 to 276 bar gauge) to produce hydrogenation reaction of the coal;

(c) withdrawing a reacted combined effluent stream containing gaseous and liquid fractions from the reactor while simultaneously deflecting particulate unconverted coal solids in the upflowing slurry liquid away from the effluent withdrawal stream, thereby increasing the concentration and residence time of larger unconverted coal solids in the reactor liquid for improved conversion therein so that the remaining effluent stream withdrawn from the reactor contains fine sized solids; and

(d) separating said effluent stream into gaseous and liquid fractions and recovering hydrocarbon liquid products.

The invention also provides a reactor apparatus for treating a liquid with a gas while containing a bed of finely divided solids, which comprises:

(a) a pressurizable vessel having means for introducing liquid, gas and finely divided solids into the vessel;

(b) a withdrawal conduit extending within the upper portion of said vessel; and

(c) deflection means positioned within the upper portion of the vessel so as to shield the inlet end of said withdrawal conduit to selectively reduce the entry of larger particulate solids into the conduit.

In the improved reaction process and apparatus according to the invention for catalytic hydrogenation of coal to produce hydrocarbon liquid and gas products, coal solids are selectively retained in the reactor liquid for prolonged hydrogenation reactions and improved conversion therein. Such increased retention of coal solids in the reactor is accomplished by deflecting solid coal particles larger than about 30 microns which rise with the upflowing liquid away from the opening into the effluent stream withdrawal conduit and back into the reactor liquid. Such deflecting of fine coal solids is accomplished by suitable deflection means critically positioned in the upper portion of the reactor vessel near and associated with the withdrawal conduit. This solids deflection means, such as a baffle, provides for increased retention in the reactor of the larger particle size least reacted coal solids and semi-solids material for prolonged hydrogenation reaction under the reaction conditions. The retention of such solids having a particle size usually larger than about 30 microns and preferably within the range of 40-200 microns prolongs the residence time and thus increases the hydrogenation reaction and percentage conversion of these heavy hydrocarbon materials to lower boiling components, such as light and medium hydrocarbon liquid and gas products.

By using this reactor system having solids deflection and retention means incorporated therein, the solids

concentration in the reactor slurry liquid is increased to exceed about 15 W % and may be increased up to about 30 W % or more in the liquid. Such higher solids concentration in the reactor results in 10 - 20 W % more unconverted coal being retained in the reactor for further reaction therein, and provides improved yields of light and medium liquid fraction products from the coal. A minor portion of the reactor recycled liquid containing larger size coal and ash particles is withdrawn from the reactor as needed to maintain the solids concentration in the reactor below an allowable level, such as about 30 W %. Accordingly, this invention provides a significant increase in coal conversion reaction efficiency and increased throughput per unit reactor volume.

In accordance with the invention, an ebullated bed catalyst reactor for coal hydrogenation is provided with a solids deflection baffle or retention device used within the reactor, and such baffle is critically located within the reactor upper portion to effect the increased solids concentrations desired in the reactor liquid. The baffle is located so as to partially shield the inlet to the effluent withdrawal conduit from upflowing coal solids and thereby reduce the amount of particulate coal solids (unconverted coal and ash) entering the conduit with the combined effluent liquid and gas stream, and selectively retain such solids in the slurry liquid being recycled through the ebullated catalyst bed.

The reactor deflection baffle may be varied in position and shape. The reactor baffle can be made any shape, such as flat, curved downwardly, or conical-shaped; and is preferably attached to and supported by the withdrawal conduit. The baffle can be oriented within the reactor either horizontally or inclined with the horizontal plane at an angle from 0° to about 45°. The deflection baffle angle should usually not exceed about 45° with the horizontal, so that the larger upflowing particles will be deflected back downwardly into the reactor liquid. The centre line distance between the withdrawal conduit lower end and the upper surface of the baffle should be at least equal to the conduit inside diameter and is preferably 1.2-10 times the conduit diameter. Also the baffle is sized relative to the inside diameter of the reactor withdrawal conduit so that the horizontal projection of the baffle area exceeds the inside cross-sectional area of the conduit by about 2 to 20 times the conduit area. These dimensional and area relationships provide for selectively retaining in the reactor the desired increased concentration of unconverted coal solids for further reaction. If desired, the position of the solids deflection baffle in the reactor may be made variable for process control purposes.

This invention is particularly applicable to catalytic reaction systems having internal recycle of reactor liquid to provide the desired amount of expansion and ebullation of the catalyst bed such as for H-Coal (Trade Mark) coal liquefaction processes. Reaction conditions maintained in the reactor should be within the broad range of 750-950°F (399-510°C) temperature and 1000-4000 psi (69-276 bar) hydrogen partial pressure. The coal feed rate or space velocity should be about 5-60 pound/hr/ft^3 (80-961 kgh^{-1}m^{-3}) reactor volume. The catalyst particle size used should be sufficiently large for it to be reliably retained in the ebullated bed and not be carried out with the recycled liquid. The catalyst particles are usually larger than about 0.016 inch (400 microns) effective diameter, and preferably are in the range of 0.020 to 0.065 inch diameter (500-1600 microns). Such increased upflow velocity of reactor liquid permits greater feedstream throughput to be achieved for a particular size reactor.

For such ebullated catalyst bed reactors using internal liquid recycle, and deflection baffle is also located sufficiently removed from the top of the liquid-gas separation device (recycle cup) so as to avoid any catalyst carryover from the ebullated bed into the recycle pump. Such catalyst carryover causes undesired recirculation of catalyst particles through the liquid recycle pump, which not only causes increased attrition of the catalyst but can also cause serious erosion damage to the pump. The reactor having deflection baffle means in its upper portion is usually and preferably used for coal hydrogenation processes utilizing upflow or ebullated type catalyst beds. However, the invention can also be advantageously used for coal hydrogenation processes without an externally added catalyst, in which it is desired to maintain a high percentage of ash solids in the reaction zone for their catalytic effect of the hydroconversion reaction.

It is an additional feature of the invention that use of this deflection baffle arrangement for providing increased solids retention in the reactor permits selectively withdrawal of a low solids concentration liquid effluent stream from the upper portion of the reactor, and also withdrawal of a high solids concentration minor stream from the internal liquid recycle loop separately from the reactor upper effluent stream. Because a portion of the liquid-solids separation for the coal hydrogenation process occurs within the reactor, this arrangement thereby reduces the downstream liquid-solids separation requirements of the process. The high solids concentration stream can usually be successfully processed in a vacuum distillation step, and the heavy vacuum bottoms portion containing high concentration of solids can be used either as fuel, or as a feed for producing the hydrogen needed in the process.

If the reactor is operated at high feed rates or space velocities which results in more unconverted coal in the product streams, it may be necessary to remove some of the coal solids from the recycle liquid stream. Such solids removal may be accomplished in a solvent precipitation step instead of using expensive hydroclones for liquid-solids separation.

Reference is now made to the accompanying drawings, in which:

Figure 1 is a schematic diagram showing the principal elements of a liquid phase catalytic reaction process for hydrogenating coal, using a reactor containing a solids deflection means;

Figure 2 shows part of a typical reactor containing a conical-shaped solids deflection means;

Figure 3 shows a typical coal liquefaction process utilizing a reactor containing solids deflection means, and from which streams having varying solids concentration are withdrawn from the reactor for further

processing; and

Figure 4 is a graph showing the typical relationship between reactor liquid recycle flow rate and weight percent coal solids in the reactor liquid.

As shown in Figure 1, coal at 10, such as bituminous or sub-bituminous coal having an ash content of 5-12 W %, is usually ground, dried, and screened at 12, and is sized to substantially all pass 30 mesh screen (0.023 inch or 0.589 mm) and preferably is 40-325 mesh screen size (0.0165-0017 inch or 0.422-0.044 mm) U.S. Sieve Series. The particulate coal is then conveyed in line 13 and slurried at 14 with a slurrying oil 15 to provide an oil/coal weight ratio ranging from about 1 to about 5. The resulting coal-oil slurry at 16 is pressurized at 18 to elevated pressure and is combined with a hydrogen rich-gas at 20. The coal-liquid-gas mixture is then heated at heater 21 and introduced through a flow distributor 22 into the bottom of an upflow hydrogenation reactor 24 containing an ebullated catalyst bed 25, having a bed level 25a, usually having a catalyst particle size of 0.020 to 0.065 inch (500-1600 microns).

The reactor 24 is adapted for providing a liquid-phase reaction of the coal, gas and a particulate hydrogenation catalyst placed in random motion therein by the upflowing liquid. The reaction conditions are preferably maintained within the ranges of 780-900°F (416-482°C) temperature and 1500-3500 psi (103-241 bar) hydrogen partial pressure. The coal feed rate should preferably be about 10-40 pound/hr/ft^3 (160-641 kgh^{-1}m^{-3}) reactor volume. The reactor liquid having a level 31 is preferably recycled internally downward through a recycle cup 26 and downcomer conduit 27 to a recycle pump 28 so as to maintain the desired extent of catalyst bed expansion in the reactor, such as about 10 to 100 percent over the bed settled height. This reactor liquid recycle rate usually ranges from about 20-50 gallons per minute per ft^2 (0.0815-0.2037 1 min^{-1} cm^{-2}) reactor cross-sectional area. Fresh catalyst is added at connection 23a and used catalyst is withdrawn at 23b as needed to maintain the desired catalytic activity in the reactor.

As also shown in Figure 1, a deflection means such as a baffle 30 is provided in the vapour disengagement zone 26a located above the liquid recycle cup 26. The baffle 30 is solid and oriented in such position so as to deflect upflowing coal solids downwardly, and thus partially shield the opening 32a to the effluent withdrawal conduit 32. The baffle 30 thereby provides for a partial separation of fine unconverted coal and ash solids from larger sized solids in the reactor, and thus selectively reduces the percentage of larger coal solids entering the withdrawal conduit 32 along with combined liquid and vapour portions. An increased concentration of fine unconverted coal and ash solids having a particle size preferably within the range of about 40-300 microns is retained in the reactor liquid for further reaction therein. One suitable deflector or baffle configuration for this invention includes a flat plate oriented at an angle with the horizontal of about 0 to 45 degrees, and usually having a horizontally projected area equal to about 2 to 20 times the cross-sectional area of the withdrawal conduit, as generally shown in Figure 1. The baffle 30 is preferably supported from the conduit 32 by at least three structural rods 33, as is better shown in Figure 2. The conduit 32 and connected baffle 30 are preferably made removable from the upper end of the reactor 24 through a removable bolted flange 34.

A catalytically reacted effluent stream containing combined hydrocarbon liquid and gas components is withdrawn through the conduit 32, and passed via line 35 to a phase separator 36. A gaseous stream is removed at 37, and liquid containing a minor concentration of fine solids is removed at 39. Also, if desired, a portion 39a of the recycle liquid stream 39 containing increased concentration of coal and ash solids can be withdrawn from the reactor for separate processing.

Another suitable deflection baffle configuration is a conical-shaped baffle 38 as shown in Figure 2, with the cone apex oriented upwardly and centrally aligned with the effluent conduit 32. Reference numerals in Figure 2 have the same meaning as corresponding ones in Figure 1. The baffle conical surfaces are usually oriented at an angle of 20 - 60 degrees with the horizontal, and the diameter of the downwardly-facing base of the cone can be about 2 to 10 times the inside diameter D of the withdrawal conduit. Although the flat inclined baffle 30 configuration of Figure 1 is suitable for use in reactors having an inside diameter up to about 1.5 feet (46 cm), a conical-shaped or a convex-shaped baffle as in Figure 2 is preferred for use in larger diameter reactors.

A further embodiment of this invention is shown in Figure 3, which is an extension of the Figure 1 reactor configuration. Corresponding reference numerals have the same meaning in Figure 1 and Figure 3. From the ebullated catalytic bed reactor 24, an effluent stream 41 containing liquid and vapour fractions is withdrawn from the upper part of the reactor through a conduit 40 above the catalyst bed level 25a and liquid level 31. As shown, the lower end of the vertical withdrawal conduit 40 is bent by at least about 90°, so that the lower surface 40a of the conduit or an extension thereof acts as a solids deflecting surface similarly to the baffles 30 and 38. The effluent stream 41 contains a lesser concentration of unconverted coal and ash solids compared to the reactor liquid, and is withdrawn through the removable conduit 40 located near the top of the reactor.

The effluent stream 41 is passed to a hot phase separator 42, from which a vapor portion 43 and liquid portion 44 are removed separately. The resulting vapour portion 43 is passed to a hydrogen purification step 50, having a vent 50a, and from which the recovered hydrogen gas is repressurised and recycled at 51 for use as the hydrogen-rich gas at 20, along with any high purity make-up hydrogen gas needed at 20a.

The liquid condensate stream and 44 is pressure-reduced at 45 and passed to a low pressure phase separator 46, from which a resulting vapour stream 47 is passed to a fractionation system 54. Also from the separator 46, a liquid portion 48 is withdrawn and passed to a liquid-solids separation step 52, which can comprise multiple hydroclones for a solvent precipitation system. An overflow stream 53 containing a

reduced concentration of particulate solids is also passed to the fractionation system 54 where the material is usually separated by fractional distillation into a gaseous and light ends steam normally boiling up to about 450°F (232°C) removed at 55, a distillate liquid fraction normally boiling between about 450° and 650°F (232 and 343°C) removed at 56, and a bottom fraction removed at 57 having a normal boiling range in excess of 650°F (343°C) and usually about 800 to 975°F (427 to 524°C). A portion 56a of the relatively solids-free oil at 56 is usually recycled as coal slurrying oil 15 to the system. The underflow liquid stream at 59, containing an increased concentration of fine unconverted coal and ash solids, is passed to a vacuum distillation step 60. An overhead liquid stream 61 is preferably added to the distillate stream 57 to provide a heavy fuel oil product 58. The vacuum bottoms stream 62 is withdrawn as a heavy product material.

If desired, a portion of the liquid recycle stream 29, usually recycled directly to the reactor for maintaining the desired ebullation of the catalyst bed in the reactor 24, is withdrawn at 63 as a solids-enriched liquid stream for separate processing. This liquid stream containing an increased concentration of coal solids, such as 20-40 W % solids, is pressure-reduced at 65 and passed with the underflow stream 59 to the vacuum distillation step 60. The vacuum overhead stream 61 may be combined with the liquid product 58, while the bottoms stream 62 may be passed to a coking step or serve as feedstock for producing the hydrogen needed in the system.

It is an advantage of this invention that the solids deflection means provided in the reactor upper end provides sufficient solids separation that an external conventional solids separation step such as by hydroclones, centrifuge filtration or solvent precipitation, is minimized or may even be eliminated depending upon the acceptable solids concentration level in the product oil streams. Thus, elimination of such an external solids separation step reduces the process cost and complexity.

This invention will be further described by reference to the following Example of operations.

Example

Illinois No. 6 bituminous coal having 50-300 mesh size (U.S. Sieve Series) was fed as a coal/oil slurry with hydrogen into a 6-inch (15 cm) diameter reactor containing an ebullated catalyst bed, maintained under elevated temperature and pressure conditions, to produce hydrocarbon liquid and gas products. The reactor was provided with a flat metal baffle about 4-inch (10 cm) average diameter, positioned at a 45° angle with the horizontal plane and having its centre located about 1.3 inches (3.3 cm) upstream of a 1.125 inch (2.858 cm) inside diameter withdrawal conduit, similarly as shown in Figure 1. The operating conditions and results for the catalytic reaction step with and without the baffle and for otherwise quite similar operating conditions are provided in Table 1 below.

TABLE 1

Ebullated bed reactor operations with and without retention of coal solids

	Run No. 130-66 Without Baffle In Reactor		*Run No. 130-67 With Baffle In Reactor*	
Coal Feed, W % Water	2.82		1.87	
Coal Feed, W % Ash	11.07		10.93	
Coal Feed Rate, Lbs/Hr (Kgh^{-1})	164	(74.4)	177	(80.3)
Hydrogen Makeup, SCFH	1890		1890	
Catalyst Bed Expansion, %	50		50	
Recycle Gas, SCFH	1075		1676	
Recycle Oil, SCFH	410		451	
Reactor Temperature, °F (°C)	826	(441)	831	(444)
Reactor H_2 Pressure, psig (bar gauge)	2700	(186)	2700	(186)
Internal Slurry Recycle Rate,				
Gpm/FT^2 Reactor (Average)	48		34	
Start of Run	43		46	
After 8 Hours	52		36	

It is noted that a significantly lower internal slurry recycle rate was required for producing the desired 50% catalyst bed expansion in Run No. 130-67, using the internal deflection baffle, actually reflecting a reduction of about 30% in the rate during the period of operation. The general relationship between the reactor liquid recycle rate for 50% catalyst bed expansion and the percent total solids in the reactor liquid, i.e. unconverted coal and ash or mineral matter, is shown in Figure 4, and is based on data subsequently obtained for catalytic hydrogenation of coal. Thus, this reduced liquid recycle rate required for Run No. 130-67 to achieve the same catalyst bed expansion indicates increased density and viscosity of the reactor liquid. The differences in the operating conditions are not sufficient to have any substantial effect on the internal recycle liquid requirements. Thus, it is seen that the internal deflection baffle means provides for increased viscosity and coal solids concentration in the reactor liquid. This indicates that increased conversion of the coal solids can

be achieved by use of such deflecting means critically located upstream of the reactor effluent withdrawal conduit, and also that separation of unconverted coal and ash solids can be achieved in the ebullated bed reactor system by such solids deflection means.

CLAIMS

1. A process for hydrogenation of coal to produce hydrocarbon liquid and gas products, comprising:

(a) slurrying the coal with a hydrocarbon liquid and feeding the coal-oil slurry and hydrogen gas into a reactor containing particulate contact solids;

(b) passing said coal slurry and gas upwardly through the reactor under liquid phase conditions in which the solids are placed in random motion in the upflowing liquid, and at a temperature from 750 to 950°F (399 to 510°C) and hydrogen partial presssure from 1000 to 4000 psig (69 to 276 bar gauge) to produce hydrogenation reaction of the coal;

(c) withdrawing a reacted combined effluent stream containing gaseous and liquid fractions from the reactor while simultaneously deflecting particulate unconverted coal solids in the upflowing slurry liquid away from the effluent withdrawal stream, thereby increasing the concentration and residence time of larger unconverted coal solids in the reactor liquid for improved conversion therein so that the remaining effluent stream withdrawn from the reactor contains fine sized solids; and

(d) separating said effluent stream into gaseous and liquid fractions and recovering hydrocarbon liquid products.

2. A process as claimed in claim 1, wherein the effluent stream withdrawn from the reactor has a solids concentration less than the solids concentration maintained in the reactor liquid.

3. A process as claimed in claim 1 or 2, wherein the reactor contains an ebullated bed of particulate catalyst having a particle size larger than 0.016 inch (0.41 mm) effective diameter.

4. A process as claimed in any of claims 1 to 3, wherein the coal feed has a particle size range of 30 to 325 mesh (U.S. Sieve Series) and the coal-oil slurry contains a coal/oil weight ratio of from 1 to 5.

5. A process as claimed in any of claims 1 to 4, wherein the fine sized coal solids in the effluent stream withdrawn from the reactor are smaller than 50 microns.

6. A process as claimed in any of claims 1 to 5, wherein a minor portion of the reactor slurry liquid is withdrawn from the bottom of the reactor for further processing.

7. A process as claimed in claim 6, wherein a liquid stream having a coal and ash solids concentration exceeding 15 weight percent is withdrawn from the reactor liquid, and subjected to a low pressure distillation step.

8. A process as claimed in any of claims 1 to 7, wherein the deflection of particulate coal solids away from the reactor effluent withdrawal stream is varied so as to control the percent unconverted coal solids in the effluent liquid stream.

9. A process for the catalytic hydrogenation of coal to produce hydrocarbon liquid and gas products, which comprises:

(a) passing the coal in particulate form with a slurrying oil and hydrogen gas upwardly through an expanded bed of catalytic solids in a reactor while maintaining the reactor under hydrogenation conditions of temperature in the range of 780-900°F (416-482°C) and hydrogen partial pressure from 1500-3500 psig (103-241 bar gauge) and hydrogenating the coal;

(b) withdrawing a hydrogenated effluent stream containing hydrocarbon gaseous and liquid fractions from the reactor upper end, while simultaneously deflecting unconverted coal solids larger than 30 microns into the reactor liquid away from said effluent stream, so that the effluent stream contains a coal solids concentration less than the solids concentration in the reactor liquid;

(c) phase separating the reactor effluent stream into gas and liquid portions;

(d) passing the liquid portion to a liquid-solids separation step for partial removal of particulate solids from the liquid;

(e) fractionating the remaining liquid containing reduced solids concentration to provide at least three fractions comprising a light ends fraction, a middle distillate liquid fraction, and a bottom liquid fraction;

(f) recycling a portion of said middle liquid fraction to the reactor for slurrying the coal; and

(g) withdrawing from the fractionation step said liquid product streams.

10. A process for hydrogenating coal to produce hydrocarbon liquid and gas products, wherein a coal-oil slurry is provided and introduced with hydrogen into a reactor containing an ebullated bed of particulate catalyst, said reactor being maintained within a temperature range of 750-950°F (399-510°C) and hydrogen partial pressure of 1500-4000 psig (103-276 bar gauge) and a liquid slurry is recycled in the reactor to hydrogenate the coal and produce hydrocarbon liquid and gaseous material, characterised by

(a) retaining unconverted coal solids larger than 30 microns in the reactor liquid by deflecting such solid particles in the upflowing liquid slurry by a solids deflecting means located upstream of the withdrawal conduit, said coal solids being deflected downwardly into the reactor liquid; and

(b) withdrawing an effluent stream from said reactor upper end, said stream containing gaseous and liquid fractions and containing coal solids particles smaller than 50 microns.

11. A process as claimed in claim 10, wherein the solids concentration in the reactor liquid is at least 5 W % greater than the coal solids concentration in the reactor effluent stream.

12. A reactor apparatus for treating a liquid with a gas while containing a bed of finely divided solids, which comprises:

(a) a pressurizable vessel having means for introducing liquid, gas and finely divided solids into the vessel;

(b) a withdrawal conduit extending within the upper portion of said vessel; and

(c) deflection means positioned within the upper portion of the vessel so as to shield the inlet end of said withdrawal conduit to selectively reduce the entry of larger particulate solids into the conduit.

13. Apparatus as claimed in claim 12, wherein the deflection means is a baffle having an area which exceeds the withdrawal conduit opening area.

14. Apparatus as claimed in claim 13, wherein the baffle is solid and is attached to and supported by the withdrawal conduit.

15. Apparatus as claimed in claim 13 or 14, wherein the withdrawal conduit is positioned substantially vertically and the baffle is inclined to the horizontal at an angle of 0-45 degrees.

16. Apparatus as claimed in any of claims 13 to 15, wherein the horizontally projected area of the baffle exceeds the cross-sectional area of the withdrawal conduit.

17. Apparatus as claimed in any of claims 13 to 16, wherein the vertical spacing between the withdrawal conduit lower end and the baffle exceeds the inside diameter of the withdrawal conduit.

18. Apparatus as claimed in any of claims 13 to 17, wherein the baffle is conical-shaped with the larger diameter facing downwardly.

19. Apparatus as claimed in any of claims 13 to 18, wherein the withdrawal conduit and baffle are removable through a flanged opening in the upper end of the reactor.

20. Apparatus as claimed in any of claims 12 to 19, wherein the deflection means is made moveable to the withdrawal conduit lower end.

21. A reactor apparatus for treating a liquid with a gas while containing a bed of finely divided solids, which comprises:

(a) a pressurizable vessel having means for introducing liquid, gas and finely divided solids into the vessel;

(b) a withdrawal conduit extending within the upper portion of said vessel; and

(c) solid deflection baffle means attached to said withdrawal conduit so as to partially shield the inlet end of said conduit to selectively reduce the entry of larger particulate solids into the conduit.

22. A process for hydrogenation of coal substantially as hereinbefore described with reference to the Example and/or the accompanying drawings.

23. Hydrocarbon liquid or gas products when produced by a process as claimed in any of claims 1 to 11 and 22.

24. A reactor apparatus substantially as hereinbefore described with reference of the accompanying drawings.

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